SPECIFICATION

VERTICAL FURNACE AND WAFER BOAT FOR VERTICAL FURNACE

Technical Field

The present invention relates to a vertical furnace and a wafer boat incorporated in a vertical furnace, and in particular to a vertical wafer boat incorporated in a vertical diffusion furnace or a vertical vapor growth furnace.

Background Of The Invention

In an oxidation and diffusion process for semiconductor wafers, a wafer boat carrying thereon several semiconductor wafers is introduced into a diffusion furnace so as to subject the semiconductor wafers to a predetermined heat-treatment process. There may be used a vertical wafer boat or a horizontal wafer boat in accordance with a type of the diffusion furnace.

There has been conventionally used a wafer boat having a structure for holding a wafer at three or four points, and having rod-like support parts which project from the boat, and boat support columns in order to support the wafer having its peripheral end parts and its rear surface of the wafer made into surface contact with the boat support columns and the support parts, respectively. (Japanese Patent Laid-

Open No. S61-191015).

Further, there has been used a wafer boat in which the boat support columns are formed therein with grooves having a thickness slightly larger than the thickness of a wafer, for supporting a wafer having its peripheral end part and the peripheral part of its rear surface made into surface contact with the grooves.

These years, there has been such a tendency that the diameter of wafers has been larger and larger. In particular, should a wafer have a diameter larger than 30 cm (12 inch), the wafer would be warped by its dead weight, finally causing a problem of occurrence of crystal defect such as a slip. In order to solve this problem, a boat which supports a wafer at positions far from the peripheral part of the wafer but near to the center thereof has been used (Japanese Laid-Open Patent No. H06-169010 and Japanese Laid-Open Patent No. H09-139352).

Alternatively, arcuate or ring-like support members are provided to the boat support columns so as to support the wafer having the peripheral edge part of its rear surface made into surface contact with these members (Japanese Laid-Open Patent No. H6-260438).

Disclosure Of Invention

In the conventional technology for supporting a wafer in a point contact manner, the contact area is inevitably limited even though the inside part of the

wafer is supported, and accordingly, a wafer having a large dead weight causes stress to increase at a supported position, and its yield stress to decrease due to a higher process temperature. Thus, a generated stress readily exceeds the yield stress, resulting in occurrence of a slip.

Further, it has been required for supporting a wafer to form deep slits or support rods in and on the support members, and accordingly, there has been raised a problem of increasing the time and labor, and as well a problem of increasing the costs.

As mentioned above, there has been used such a conventional technology that a wafer is supported at its peripheral edge by an arcuate or ring-like support member through surface-contact. However, even in this configuration, there has been a problem such that a slip inevitably occurs even under such a condition that the process temperature for the wafer exceeds 1,000 deg.C.

In order to solve the above-mentioned problem, in a vertical wafer boat in which a wafer is made into surface-contact with the upper surface of the arcuate or ring-like support so as to support the wafer, the support member is formed in its upper surface with groove-like cutouts at positions which make an angle of 45 deg. with respect to the wafer inserting direction of the wafer boat at the center of the arcuate or ring-like support member in order to

prevent the support members from making contact with the wafer.

Explanation will be made of the reason why the above-mentioned configuration has been taken. Even though the lower surface of the wafer is made into surface contact with the arcuate or ring-like support member so as to support the wafer, the support member is not made into contact with the lower surface of the wafer over its entire surface. That is, microscopically, the wafer is supported in such a condition that the support member is in part made into contact with the wafer due to a warp of the wafer or the support member, caused by their deadweights or temperature distribution, or unevenness due to surface roughness, manufacturing accuracy and the like. Accordingly, a stress which is greater than that obtained when it is uniformly contact with the wafer is presented at a contact position.

Table 1 shows the relationship between the position where a slip occurs and the frequency thereof in such a case that a wafer having a diameter of about 30 cm (12 inches) and using {001} as a principal planes is set so as to align a <110> direction with its inserting direction and is supported by a ring-like support member, and they are thermally treated at temperatures 1050 deg.C, 1,100 deg.C and 1,200 deg.C. The position of occurrence of a slip is indicated by a center angle of 0 to 45 deg. with respect to the wafer

inserting direction with the estimation of a 1/8 mirror surface symmetry. From Table 1, it is found that the frequency of occurrence of a slip is higher at a position around the center angle of 45 deg. than that at any other position. That is, the wafer using {001} as a principal plane and <110> direction as an inserting direction exhibits such a tendency that a slip possibly occurs at positions which make a center angle of 45 deg. with respect to the wafer inserting direction, that is, in four directions of <100>, <010>, <100> and <0-10>. Accordingly, with the prevention of contact between the wafer and the support member in this four directions, it is possible to restrain occurrence of a slip.

Table 1

		Position (Center Angle)					
		0~7.5	7.5~15	15~22.5	22.5~30	30~37.5	37.5~45
Temp. (°C)	1,050	1	1	0	0	0	4
	1,100	2	1	0	0	1	6
	1,200	2	2	5	0	0	6
Total		5	5	5	0	1	16

Brief Description Of The Drawings:

Fig. 1 is a transverse sectional view illustrating a vertical diffusion furnace (vapor phase growth furnace) in an embodiment of the present

invention;

Fig. 2 is a view illustrating an entire configuration of a vertical wafer boat in the embodiment of the present invention;

Fig. 3 is a cross-sectional view along line A-A' in Fig. 1, illustrating the vertical wafer boat in the first embodiment of the present invention;

Fig. 4 is a plan view illustrating a support member in the vertical wafer boat, for explaining the configuration of the embodiment of the present invention;

Fig. 5 is side views illustrating shapes of a groove in the support member of the vertical wafer boat in the embodiment of the present invention;

Fig. 6 is a plan view illustrating the support member of the vertical wafer boat in another embodiment of the present invention;

Fig. 7 is a plan view illustrating support member in the vertical wafer boat in further another embodiment of the present invention;

Fig. 8 is a plan view illustrating a support member in a vertical wafer boat in further another embodiment of the present invention;

Fig. 9 is a plan view illustrating a support member in a vertical wafer boat in further another embodiment of the present invention;

Fig. 10 is a plan view illustrating a support member in a vertical wafer boat in further another

embodiment of the present invention;

Fig. 11 is a plan view illustrating a support member in a vertical wafer boat in further another embodiment of the present invention;

Fig. 12 is a plan view illustrating a support member in a vertical wafer boat in further another embodiment of the present invention; and

Fig. 13 is a view showing a relationship between a center angle of a groove in the support member of a vertical wafer boat in further another embodiment of the present invention, and a stress generated in a wafer.

Best Modes Of The Invention

Explanation will be hereinbelow made of the present invention with reference to the drawings.

Referring to Fig. 1, a reaction pipe incorporated in a vertical resistance heating furnace 1 has a double structure composed of an outer tube 2 and an inner tube 3, and is supported on a base 4. Reaction gas is fed into the inner tube 3, and is extracted from the inner tube 2. A boat 5 is set in the inner tube 3, and inserted into and pulled out from the inner tube 3 through a circular hole 6 formed in the center part of the base 4. Wafers are held in the boat 5 at arbitrary intervals in the vertical direction. The wafers are shifted to and from the boat 5 taken out from the inner tube 3.

Referring to Fig. 2 which is a view illustrating the entire configuration of the boat 5, the boat 5 comprises a plurality of support columns 8, a top panel 51, a bottom panel 62 and a cap 53.

Referring to Fig. 3 which is a cross-sectional view along line A-A' in Fig. 1 as viewed in the vertical direction, illustrating the boat 5, the boat 5 holding therein a plurality of wafers 7 in substantially horizontal postures comprises a plurality of support columns 8, and a plurality of support members 9. The plurality of support columns 8 are planted substantially upright, surrounding the peripheries of the wafers 7 held in the boat 5. Since the wafers 7 are inserted in a horizontal direction into the boat 5, the space between the support columns 8 is widened in the insertion part therefore in order to ensure an insertion space for the wafers 7. The support members 9 have an arcuate or ring-like shape, and are integrally incorporated with the support columns 8 or are removablly held in grooves formed in the support columns 8. The support members 9 hold the wafers 7, concentric with each other. That is, in the supported condition, the centers of the wafers 7 are substantially coincident with the centers of the arcs or rings of the support members 9. It is noted that the inserting direction of each wafer 7 is set so as to pass through the center of the associated support member 9.

Referring Fig. 4 which is an example of the support member 9 in this embodiment, the support member 9 is ring-like, and is formed in its upper surface with four grooves in directions which make an angle of 45 deg. with respect to the wafer inserting direction at the center of the ring of the support member 9. These grooves prevent the lower surface of a {001} wafer 7 from making contact with the support member 9 in <100> , <010>, <-100> and <0-10> directions.

The grooves 10 have a rectangular cross-sectional shape.

However the grooves 10 may have any of various shapes if it has a depth with which the lower surface of the wafer 7 can be prevented from the upper surface of the support member 9, that is, it may be a recess, a hole or the like. Fig. 5 is side views which show examples of the grooves 10. In addition, the grooves shown Fig. 5(a) (corners of a rectangular cross-sectional shape of the groove have a curvature), Fig. 5(b) (corners of a rectangular cross-sectional shape of the groove are chamfered), Fig. 5(c) (a groove having a V-like cross-sectional shape, Fig. 5(d) (a groove having a trapezoidal cross-sectional shape), and Fig. 5(e) (a corner of a V-like or trapezoidal cross-sectional shape of a groove has a curvature) exhibit similar technical effects and advantages.

The wafer 7 and the support member 9 are made into point or line contact with each other at end parts

of the grooves or cutouts or surface contact which is substantially identical with point or line contact, with the each other, and accordingly, large stresses would be possibly caused in the parts of the wafer 7 which make contact with the end parts of the grooves or cutouts. Accordingly, it is desirable that the grooves and cutouts are formed so as to have curvatures at the end parts or edges thereof in order to increase the contact areas of the wafer at the end parts of the grooves or cutouts, since there has been such an effect that the stresses can be reduced.

Even though the grooves and cutouts exhibit such an effect as to restrain occurrence of inappropriate stresses which are caused by contact between the grooves or cutouts and the wafer so as to result in occurrence of a slip, it is natural that the wafer cannot be supported by the support member in zones where the grooves or cutouts are formed. Accordingly, the wafer is bent in these zone due to the deadweight of the wafer. The greater the circumferential width of the grooves or cutouts, the higher the stresses. It is required that the circumferential width of the grooves or cutouts is set to an appropriate value.

Referring to Fig. 13 which shows a result of FEM analysis of circumferential stress caused at the centers of grooves in the wafer with respect to center angles of the grooves as parameters, in such a case

that a wafer having a diameter of 30 cm (12 inches) and having {001} as a principal plane is supported by a support member formed therein with grooves at positions making angle of 45 deg. with respect to the inserting direction of the wafer with such an estimation that the groove width has a certain center (the angle of an arc in such a case that the groove width is regarded as an arc), the stress is exhibited by a ratio to a stress caused a groove having a center angle of zero, that is, no groove is present.

Accordingly, the center angle of the grooves or cutouts is preferably less than 12 deg. with which an increment of the stress caused by each of the grooves or cutouts does not exceed 1/10 of a stress which is caused when no groove in present, and if possible, it is preferably less than 6 deg. with which the increment of the stress can be less than 1/100. It is noted that in this embodiment, the center angle is set to about 4 deg.

Fig. 6 shows another example of the support member 9. In the support member 9 in this embodiment, an arcuate part forward in the direction of wafer insertion is widely opened in order to enable a shifting device for the wafers 7 to be inserted therethrough. If the part has a suitable width so that the supporting of the wafer becomes uneven so as to cause stresses, no slip is caused.

Fig. 7 shows further another example of the

support member 9, instead of the grooves 10, cutouts 11 are formed in the support member 9. In this structure, the thickness of the support member 9 can be reduced in comparison with that formed therein with the grooves 10, and as a result, there can be provided a wafer boat in which a larger number of the wafer can be mounted although the boat has an equal height. Further, with this structure, although a high stress is caused in a narrow part of the cutout, by suitably designing the structure and by suitably selecting a material, the reliability can be ensured.

Referring to Fig. 8 which shows further another example of the support member 9, in order to insert the wafer shifting device behind the wafer, the outer peripheral side of the support member 9 is set back outward so as to ensure a space inward in the wafer inserting direction. Alternatively, the curvature may be increased in this part.

Further, as shown in Fig. 9, even though the groove 10 is not formed in every of all four directions, but is formed in some thereof, the provability of occurrence of a slip can be reduced, that is, the number of slips caused in a single wafer can be reduced, thereby it is possible to effect such an advantage that the yield of the device can be increased.

Further, referring to Fig. 10 which shows another example of the support member 9. The thinner

the wall thickness, the lower the rigidity, the wafer could not be supported or the stress caused by contact would be increased, resulting in a main cause of occurrence of a slip. However, if the wall thickness is increased, pitches of the grooves for supporting the support members become larger, and accordingly, the number of wafers which can be mounted on the boat 5 at a time, is inevitably decreased. Further, should the wall thickness be increased, the weight would be increased, and accordingly, the load to the support columns of the boat would be increased or the overall size of the device would become huge. Further, it causes an increase in the costs. In the embodiment shown in Fig. 10, the support member 9 has a L-like cross-sectional shape. The wall thickness of parts of the support member where the support member is mounted or removed is small but that of the other parts is large. Thus, the pitches of grooves for mounting and removing the support members can be prevented from increasing, and further, the weight can be restrained from increasing, thereby it is possible to ensure the rigidity of the support member 9. In order to reduce the weight of the support member 9 without lowering the rigidity of the support member 9, instead of increasing the wall thickness, it is effective to form reinforcing ribs at the rear surface of the support member, in the circumferential or radial direction thereof.

Referring to Fig. 11 which shows further

another example of the support member 9, the support member 9 has an arcuate shape so that a part at least from an angle of -45 deg. to an angle of +45 deg. with respect to the inserting direction of the wafer at the center of the arc of the support member 9 is opened forward in the direction of the wafer insertion in order to prevent the wafer from making contact with the support member at a position where the yield stress become smallest and in order to enable the insertion of the wafer shifting device.

Referring Fig. 12 which shows further another example of the support members 9, the support members 9 are integrally incorporated with the support columns 8.

According to the present invention, the diameter of the wafer is increased, the occurrence of stress due to contact with the support member in the case of increasing the process temperature can be restrained, and accordingly, it is possible to prevent occurrence of a slip in the contact part between the wafer and the boat during heat treatment in a vertical diffusion furnace or a vertical vapor growth furnace. As a result, affection upon the device characteristic due to a slip can be eliminated, thereby it is possible to exhibit a remarkable effect for enhancing the yield of devices.